

The variability of the CoRoT target HD171834: γ Dor pulsations and/or activity? *

K. Uytterhoeven^{1, **}, P. Mathias², A. Baglin³, M. Rainer⁴, E. Poretti⁴, P. Amado⁵, E. Chapellier⁶, L. Mantegazza⁴, K. Pollard⁷, J.C. Suarez⁵, P.M. Kilmartin⁷, K.H. Sato¹, R.A. García¹, M. Auvergne³, E. Michel³, R. Samadi³, C. Catala³, and F. Baudin⁸

¹ Laboratoire AIM, CEA/DSM-CNRS-Université Paris Diderot; CEA, IRFU, SAp, centre de Saclay, 91191, Gif-sur-Yvette, France

² Laboratoire d'Astrophysique de Toulouse-Tarbes, Université de Toulouse, CNRS, 57 Avenue Azereix, 65000 Tarbes, France

³ LESIA, UMR8109, Université Pierre et Marie Curie, Université Denis Diderot, Observatoire de Paris, 92195 Meudon, France

⁴ INAF-Osservatorio Astronomico di Brera, Via E. Bianchi 46, 23807 Merate, Italy

⁵ Instituto de Astrofísica de Andalucía (CSIC), Apartado 3004, 18080 Granada, Spain

⁶ UMR 6525 H. Fizeau, UNS, CNRS, OCA, Campus Valrose, 06108 Nice Cedex 2, France

⁷ Dep. of Physics and Astronomy, University of Canterbury, Private Bag 4800, Christchurch, New Zealand

⁸ Institut d'Astrophysique Spatiale, UMR 8617, Université Paris XI, Bâtiment 121, 91405 Orsay Cedex, France

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We present the preliminary results of a frequency and line-profile analysis of the CoRoT γ Dor candidate HD171834. The data consist of 149 days of CoRoT light curves and a ground-based dataset of more than 1400 high-resolution spectra, obtained with six different instruments. Low-amplitude frequencies between 0 and 5 d^{-1} , dominated by a frequency near 0.96 d^{-1} and several of its harmonics, are detected. These findings suggest that HD171834 is not a mere γ Dor pulsator and that stellar activity plays an important role in its variable behaviour.

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1 Introduction

It are exciting times for seismic studies of γ Dor pulsators, thanks to the successful operation of asteroseismic space missions, such as CoRoT (Baglin et al. 2006) and Kepler (Gilliland et al. 2010). The class of γ Dor stars (Kaye et al. 1999) consists of stars of spectral types A-F that are slightly more massive than the Sun ($1.2 M_{\odot} < M < 2.5 M_{\odot}$). They pulsate in high-order, non-radial gravity (g-) mode pulsations, explained in terms of a flux modulation induced by the upper convective layer (Guzik et al. 2000; Dupret

et al. 2005; Grigahcène 2005). As only g-modes allow the probing of the deep stellar interior, γ Dor stars are extremely interesting asteroseismic targets (e.g. Miglio et al. 2008).

The γ Dor pulsators are however very challenging targets, both from an observational as theoretical point of view. Their pulsation periods are of order of a day and hence very difficult to monitor from the ground. Moreover, the corresponding pulsation amplitudes are fairly small (below 0.05 mag and 2 km s^{-1}). Several ground-based observational efforts have been undertaken to describe the pulsational behaviour in as many class members as possible (e.g. Poretti et al. 2002; Mathias et al. 2004; De Cat et al. 2006; Rodríguez et al. 2006a,b; Uytterhoeven et al. 2008; Cuypers et al. 2009), resulting in the detection and identification of only a limited amount of frequencies and associated mode parameters. Theoretically, the fast rotation observed in several γ Dor stars is posing problems in the description of the pulsational instability, as the current models do not account for higher-order rotational effects (Suárez et al. 2005; Bouabid et al. 2008, 2009; Moya et al. 2008).

The CoRoT satellite disclosed for the first time the very rich and complicated frequency spectrum, consisting of several hundreds of frequencies, of a γ Dor star (HD 49434, Chapellier et al. 2010). The first Kepler data of hundreds

* Based on observations made with ESO Telescopes at the La Silla Observatory under the ESO Large Programmes ESO LP 178.D-0361 and ESO LP 182.D-0356, and on data collected at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated jointly by the Max-Planck Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC). Based on observations made with the Nordic Optical Telescope, operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway, and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. Also based on observations made at Observatoire de Haute Provence (France) and at Mount John University Observatory (New Zealand). The CoRoT space mission has been developed and is operated by the French Space agency CNES in collaboration with the Science Programs of ESA, ESA, Austria, Belgium, Brazil, Germany and Spain.

** e-mail: katrien.uytterhoeven@cea.fr

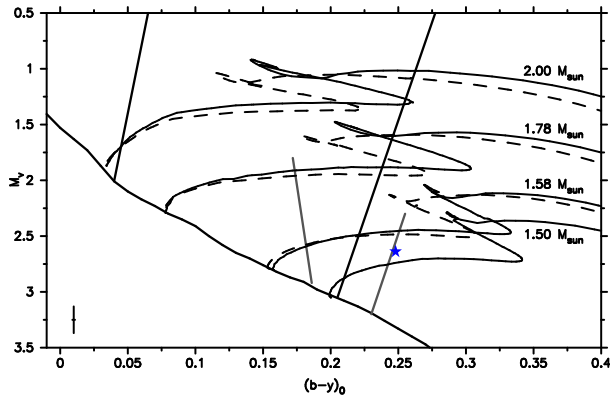


Fig. 1 Colour-magnitude diagram with the position of HD171834 indicated (star). Dashed and solid tracks are evolutionary tracks for the overshooting extension distances 0.1 and 0.2 (Claret 1995). The ZAMS, the borders of the δ Sct (black) and γ Dor (gray) instability strips are indicated by full lines (Dupret et al. 2005).

of γ Dor candidates reveal similar dense frequency spectra (Grigahcène et al. 2010), opening new perspectives in the study of the so far not-well understood class of γ Dor pulsators. Moreover, the space data promise further investigation of the nature of hybrid γ Dor- δ Sct pulsators, i.e. stars that pulsate in g - and p -modes simultaneously, as several hybrid candidates have been identified among the CoRoT and Kepler targets (Mathias et al. 2009; Grigahcène et al. 2010).

2 The γ Dor candidate HD171834

The target of this paper is HD171834 (HIP91237; F3V; $V_{\text{mag}} = 5.44$). The star lies close to the red border of the γ Dor instability strip (see Fig. 1), with effective temperature $T_{\text{eff}} = 6750 \pm 250$ K, surface gravity $\log g = 3.9 \pm 0.25$, and metallicity $[\text{Fe}/\text{H}] = -0.5 \pm 0.15$ (Lastenet et al. 2001). The γ Dor candidate HD171834 appears to be photometrically constant from the ground (Poretti et al. 2003), but weak line-profile variations with low amplitudes have been reported by Mathias et al. (2004).

3 The CoRoT time-series

The CoRoT satellite observed HD171834 for 149 days during its second Long Run in the center direction (LRc2, April–September 2008). To optimise the quality of the light curves we corrected for time gaps caused by the passage of the satellite through the South Atlantic Anomaly using the inpainting algorithm (Sato et al. 2010). The inpainted light curves were subsequently detrended and analysed in frequency with the Vaníček method (Vaníček 1971). The amplitude periodogram shows no obvious peaks for frequencies higher than 15 d^{-1} (see Fig. 2). The highest amplitudes are reached for frequencies between 0 and 5 d^{-1} , with

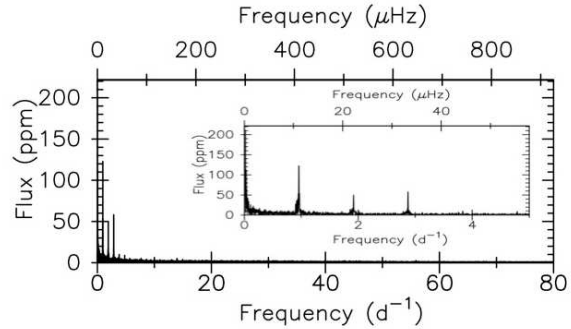


Fig. 2 Amplitude spectrum of the CoRoT data of HD171834. The inset shows the frequency region $0\text{--}5 \text{ d}^{-1}$ in more detail.

0.96 d^{-1} as dominant frequency. Harmonic frequencies seem to play an important role.

4 Ground-based spectroscopic time-series

In the framework of the ground-based follow-up observations of CoRoT targets (Uytterhoeven et al. 2008a, 2009; Uytterhoeven 2009) HD171834 was monitored for two seasons (2008 and 2009) with six different instruments (see Table 1) at the Observatory of Calar Alto (CaHa, Spain), European Southern Observatory (ESO, Chile), Observatoire de Haute Provence (OHP, France), Mount John University Observatory (MJUO, New Zealand), and Observatorio Roque de los Muchachos, La Palma (ORM, Spain). Never has there been a time-series with more than 1400 spectra for any other γ Dor star. The analysis was carried out on the Least-Squares Deconvolved (LSD, Donati et al. 1997) spectra, calculated with mask $T_{\text{eff}} = 6750 \text{ K}$ and $\log g = 4.0$, that were subsequently normalised and corrected for instrumental radial velocity shifts (see Uytterhoeven et al. 2008 for a description of the process). Figure 4 shows the radial velocities ($\langle v \rangle$) calculated from the LSD profiles. We did not find evidence for a possible binary nature of HD171834 in the spectra.

4.1 Line-profile analysis

The typical nightly line-profile variable behaviour of HD171834 is illustrated in Fig. 3. Narrow, well-defined line-profile ‘bumps’ are seen to propagate through the line-profile with periods longer than a day. The individual datasets are too short to reveal significant long-term variabilities. Therefore, we analysed the combined datasets, spanning 414 days, and excluded the more dispersed FOCES spectra as they introduced spurious frequencies (see bottom panel Fig. 4). To search for periodicities in the time-series of LSD spectra we used the Vaníček method on the velocity moments (Aerts et al. 1992), and performed a pixel-to-pixel analysis using the Intensity Period Search method (IPS, Telting & Schrijvers 1997). In the variations of the first moment the CoRoT frequency near 0.96 d^{-1} is recovered, together with sev-

Table 1 Logbook of the observations of HD171834 in 2008 and 2009. The columns give information on the instrument and observatory, the number of spectra (N), the timespan (ΔT , in days) of the dataset, the resolution of the spectrograph, and the observers.

Instrument	Observatory	N	ΔT 2008	ΔT 2009	Resolution	observer
FOCES@2.2m	CaHa	562	25.2	34.1	40,000	PJA
FEROS@2.2m	ESO	193	25.2	—	48,000	LM, KU
SOPHIE@1.93m	OHP	471	29.2	31.1	40,000	PM, KU
HERCULES@1.0m	MJUO	55	9.1	—	35,000	KP, PMK
FIES@NOT	ORM	46	—	3.4	46,000	KU
HARPS@3.6m	ESO	79	—	39.1	80,000	EP, JCS

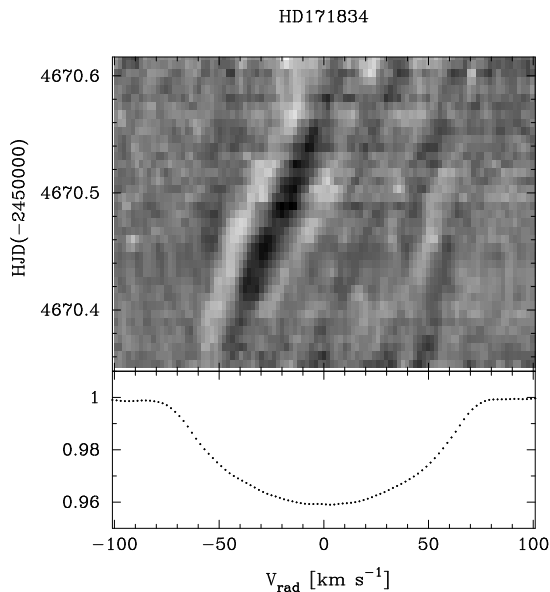


Fig. 3 Grayscale representation of one night of SOPHIE observations (HJD 2454670) illustrating the typical nightly line-profile variable behaviour of HD171834. Bottom: Average LSD profile calculated from the SOPHIE time-series consisting of 471 spectra. Top: Residual LSD profiles (HJD 2454670) with respect to the average LSD profile.

eral of its harmonics. The IPS method shows several low-amplitude frequencies between 0.1 and 1.0 d^{-1} , and harmonics of 0.96 d^{-1} .

5 Conclusions

CoRoT data reveal that the γ Dor candidate HD171834 shows low-amplitude frequencies between 0 and 5 d^{-1} , dominated by 0.96 d^{-1} and several of its harmonics, suggesting stellar activity. The long-period low-amplitude variations are difficult to detect from the ground. Only by combining all available spectra, spanning more than one season and consisting of more than 1400 spectra are the frequencies recovered. A more detailed analysis is ongoing to confirm the double nature of the variability, rotational and pulsational, and their possible connection and interplay. Also, spectropolarimetric

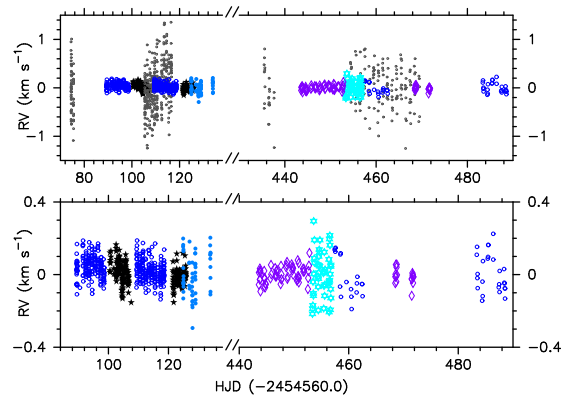


Fig. 4 Radial velocities ($\langle v \rangle$) calculated from the LSD profiles of FEROS (black filled stars), SOPHIE (blue open circles), FOCES (gray circles), HERCULES (blue filled circles), HARPS (purple diamonds), and FIES (cyan open stars) spectra (top) obtained in 2008 and 2009. In the bottom panel we did not plot the more dispersed FOCES spectra, illustrating the low amplitude variability of HD171834.

observations are scheduled with NARVAL@TBL to investigate the possible importance of a magnetic field.

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References

- Aerts, C., De Pauw, M., Waelkens, C.: 1992, A&A 266, 294
- Baglin, A., Auvergne, M., Boissard, L., et al.: 2006, in 36th COSPAR Scientific Assembly 36, 3749
- Bouabid, M.-P., Uytterhoeven, K., Miglio, A., et al.: 2008, CoAst 157, 290
- Bouabid, M. -P., Montalbán, J., Miglio, A., Dupret, M. -A., Gri-gahcène, A., Noels, A.: 2009, AIPC 1170, 477
- Chapellier, E., Rodríguez, E., Auvergne, M., et al.: 2010, A&A, submitted
- Claret, A.: 1995, A&ASS 109, 441
- Cuypers, J., Aerts, C., De Cat, P., et al.: 2009, A&A 499, 967
- De Cat, P., Eyer, L., Cuypers, J., et al.: 2006, A&A 449, 281

- Donati, J.-F., Semel, M., Carter, B.D., Rees, D. E., Collier Cameron, A.: 1997, *MNRAS* 291, 658
- Dupret, M. -A., Grigahcène, A., Garrido, R., Gabriel, M., Scuflaire, R.: 2005, *A&A* 435, 927
- Gilliland, R.L., Brown, T.M., Christensen-Dalsgaard, J., et al.: 2010, *PASP* 122, 131
- Grigahcène, A., Dupret, M. -A., Gabriel, M., Garrido, R., Scuflaire, R.: 2005, *A&A* 434, 1055
- Grigahcène, A., Antoci, V., Balona, L., et al.: 2010, *ApJ* 713, 192
- Guzik, J. A., Kaye, A. B., Bradley, P. A., Cox, A. N., Neuforge, C.: 2000, *ApJ* 542, 57
- Kaye, A.B., Handler, G., Krisciunas, K., Poretti, E., Zerbi, F.M.: 1999, *PASP* 111, 840
- Lastennet et al.: 2001, *A&A* 365, 535
- Mathias et al.: 2004, *A&A* 417, 189
- Mathias, P., Chapellier, E., Bouabid, M., et al.: 2009, *AIPC* 1170, 486
- Moya, A., Christensen-Dalsgaard, J., Charpinet, S., et al.: 2008, *AP&SS* 316, 231
- Miglio, A., Montalbán, J., Noels, A., Eggenberger, P.: 2008, *MNRAS* 386, 1487
- Poretti, E., Koen, C., Bossi, M., et al.: 2002, *A&A* 384, 513
- Poretti et al.: 2003, *A&A* 406, 203
- Rodríguez, E., Amado, P.J., Suárez, J.C., et al.: 2006a, *A&A* 450, 715
- Rodríguez, E., Costa, V., Zhou, A.-Y., et al.: 2006b, *A&A* 456, 261
- Sato, K.H., García, R.A., Pires, S., et al.: 2010, *AN*, submitted (this volume) (arXiv:1003.5178)
- Suárez, J.C., Moya, A., Martín-Ruiz, S., Amado, P.J., Grigahcène, A., Garrido, R.: 2005, *A&A* 443, 271
- Telting, J.H., Schrijvers, C.: 1997, *A&A* 317, 723
- Uytterhoeven, K., Poretti, E., Rainer, M., et al.: 2008a, *Journal of Physics Conf. Ser.* 118, 2077
- Uytterhoeven, K., Mathias, P., Poretti, E., et al.: 2008b, *A&A* 489, 2213
- Uytterhoeven, K.: 2009, *CoAst* 158, 156
- Uytterhoeven, K., Poretti, E., Mathias, P., et al.: 2009, *AIP Conf. Proc.* 1170, 327
- Vaníček, P.: 1971, *Ap&SS* 12, 10